Linear Programming Model for Production Cost Minimization at a Rice Crop Products Manufacturer

Jairo R. Coronado-Hernández, Leonardo J. Olarte-Jiménez, Zulmeira Herrera-Fontalvo(✉), and Johana Cómbita Niño

Universidad de La Costa, Barranquilla, Colombia
{jcoronad18,lolarte1,zherrera1,jcombita2}@cuc.edu.co

Abstract. Companies in general must establish processes that generate profitability at lower costs. Manufacturing of rice crop protection products requires major investments and resource planning, including infrastructure, raw materials, technology, human resources, tests and trials, among others, which represents a major challenge. This paper proposes a methodology that aims to minimize production costs taking different factors into consideration. The first section identifies and describes the variables required for modeling. In the second section a linear programming model is formulated to determine the optimal function in terms of cost reduction. Lastly, the model was applied at a real company, producing satisfactory results in terms of an improved production plan and an 11% cost reduction, while enabling viewing the variables with greatest impact, such as storage and shift programming, with cost reductions of 68% and 44%, respectively. The purpose is to assist companies in this industry in applying mathematical programming models to solve problems and enable better resource planning to improve profitability.

Keywords: Lineal programming · Rice crop · Production · Cost reduction · Production planning

1 Introduction

Worldwide, companies that manufacture crop protection products have experienced substantial growth, and the industry is forecast to grow at an annual rate of 5.5% up to 2026 [1]. This represents a challenge for the industry in terms of adapting to the market's needs and adjusting their administrative and operating structures to take advantage of this expected growth. In this context, companies must make efficient use of their resources and select suitable production plans to meet growing demand, with well-trained human resources, investment in technology and leadership for decision-making.

Manufacturers in this and all industries seek to obtain sustainable profits for their shareholders, and consequently always seek to avoid increases in costs and expenses and to reduce product manufacturing costs, in other words, to do more with less [2].

J. C. Figueroa-García et al. (Eds.): WEA 2021, CCIS 1431, pp. 335–346, 2021.
https://doi.org/10.1007/978-3-030-86702-7_29

Businesses currently use several approaches to increase profitability, including reducing the cost of supplies, optimizing the use of technology, more sophisticated information systems, improving personnel skills, reducing storage areas, and reducing shifts, among others [3]. The literature includes a wide variety of approaches and planning models based on the economics of each industry [4] aimed at increasing profitability.

This study is motivated by the above, with the aim of contributing to increasing profitability at the intervened company by designing an improved production plan, by means of a lineal programming model, based on the aggregated planning methodology, to enable better operational control and cost reductions, using as starting point the company's information and quantitative variables, historic demand, operating costs and production capacity, among others.

This study basically consists in integrating mathematical models in the solution of the actual problems faced by an economic sector, with the purpose of finding an optimal solution, additionally enabling an analysis of all the variables used to run the model, providing details on how it was developed and validating the results against the company's data, to demonstrate substantial cost reductions and manufacturing alternatives, with an improved production plan, obtaining a satisfactory result from the proposal.

2 State of the Art

Production, acquisitions planning and logistics are complex tasks at companies with several production and/or storage sites [5]. In order to achieve their production objectives and make adequate use of their resources, companies must adequately plan and control their production activities [6].

Production planning covers all the resources needed for production [7], and as a strategic decision it implies the assignment of aggregate production resources for aggregate groups of products. It is carried out in a manufacturing environment to make efficient use of these production resources to satisfy sales opportunities for finished products [8].

Production planning management can solve problems such as non-optimal production quantities, production cost ranges, production bottlenecks and unplanned production conditions [9].

Production planning activities seek to balance market needs against the optimal use of the resources available in different industries [10]. Currently, in many cases it fails to offer reliable production plans. One of the reasons is that the transition times represent a substantial proportion of the delivery time, and they are difficult to predict because they are subject to a large number of volatile and partly unknown factors [11].

Industrial processes generally involve complex manufacturing operations, and therefore require adequate decision-making support for the effects of aggregate production planning [12]. Aggregate Planning is a medium-term production planning method, covering all aspects from raw materials, labor and finished products in the medium time range to fulfill the orders [13].

Lineal Programming is used to describe optimization problems to enable finding optimal solutions in an effective manner. Unlike other heuristic models, linear programming finds an optimal solution that satisfies an objective function [14], and interested parties can use linear programming to identify the alternative route that best achieves their objectives [15]. This type of model is applied in different contexts and to find optimal solutions with parameters that comprise a system, such as specific aspects associated to an activity of a production process, as in the case of [16], who proposes a mixed-integer linear programming (MILP) model to minimize waste in the current process of cutting marble slates, with the selection of marble blocks, taking into account the cutting sequence of the slate. Other studies have focused on logistics aspects, such as the minimization of transportation costs, such as the model proposed by [17], who proposes an optimal production distribution solution from 2 production sites to 9 distributors.

Other approaches aligned with this study are related to the distribution of production activities or results, seeking the minimization of costs or waste, or the maximization of benefits or profits, through the optimization of resources. [18] proposes a mixed-integer linear programming (MILP) model to minimize costs of installation, stock outages and pending orders, in which the model aims to program production, batch size and plastic automotive components, to which end he takes into consideration the capacity of minimum and maximum stock levels and penalizes stock outages. In this study, the problem to be addressed is programming and sizing of optimal batches in flexible injection machines in parallel, applied to an automotive plastic components manufacturer.

A similar study is that by [19], who uses a mixed integer linear programming model with the main objective of minimizing production times taking into consideration an optimal number of workstations. The aim was to minimize costs and increase the production capacity of a truck assembly line at an automotive manufacturer in Indonesia, with a lean manufacturing approach and use of time study methods to obtain information for the model. Also, [20] proposes a linear programming model that establishes an optimal planting plan based on the assignment of food or diets at a dairy farm, minimizing feeding costs to the milk-producing herds.

Specifically in the case of rice crops, [21] proposes a linear programming model to optimize sales revenues of the Rejo Asri Gapoktan farmer cooperative, which has problems managing tools and machines to balance trade revenues and expenses. Using the Simplex method to optimize profits, it was found that the overall benefit obtained was 42,494,670 rupees (Indonesian currency), a major financial achievement for the farmer cooperative.

As in the above case studies, this study seeks to provide a solution to a specific need of a company in terms of the optimal use of resources, but in this case, it involves planning and the minimization of productions costs for rice crop protection products. Through the linear programming model, an optimal solution is sought from the analysis of variables determined in the model for cost reduction and an improved production plan, taking into account that resource management is an important aspect for planning production in this sector. In the literature review, no studies aligned with the study sector were found.

3 Methodology

The proposed methodology seeks to minimize production costs at a company that produces substances used in rice crops. The methodology involves 3 phases or stages. Firstly, the problem is identified and delimited, and an assessment is made of the background and main causes, to then describe the variables required for modeling. Next, the linear programming model is formulated to determine with optimal function with the objective of reducing production costs and thereby improving the company's effectiveness and productivity. To this effect, the LP Gusek specialized software for solving problems is used, which maximizes or minimizes the inputs to obtain optimal solutions. Lastly, the company's industrial data is input to run the model and obtain actual results, which enables replicating the use of the model (See Fig. 1).

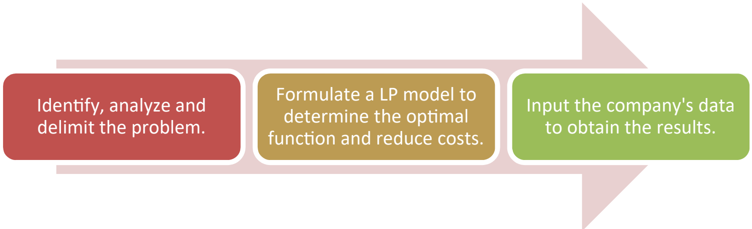

Fig. 1. Diagram of the methodological process.

4 Formulation of the Mathematical Model

The aim of a linear programming model is to optimize (minimize or maximize) a linear function, called an objective function, whose variables are subject to restrictions expressed by means of a system of equations or inequations, which enables making decisions on their impacts in any case study.

In the case of this study, the aim was to minimize production costs, including and considering variables such as machines, demand, types of products, direct manufacturing and overhead costs, cost of storage and labor. Including the variables in the model will enable making decisions on the number of units to be produced and how many to units to keep in storage to obtain the best result. Consequently, the following linear programming model was developed (Table 1):

Table 1. Set, parameters, variables.

Set
j: $Products\{P1, P2, P3, P4, P5\}$
Parameters
$D_{(j,i)} = Demand\ for\ product\ j\ in\ period\ i$
$S_{(j)} = Initial\ stock\ of\ product\ j$
$S_{\max} = Maximum\ warehouse\ storage\ capacity$
$V_{(j)} = Volume\ of\ product\ j$
$TPmax_{(i)} = Max.\ production\ time\ in\ period\ i$
$T_{(j)} = Time\ to\ manufacture\ product\ j$
$P_{(j)} = Setup\ time\ for\ product\ j$
$B_{(j)} = Production\ cost\ of\ product\ j$
$C_{(j)} = Storage\ cost\ of\ product\ j$
$CP_{(i)} = Cost\ of\ workshift\ in\ period\ i$
$CM_{(j)} = Setup\ cost\ for\ product\ j$
Variables
$x_{(j,i)} = Units\ of\ product\ j\ made\ in\ period\ i$
$y_{(j,i)} = Units\ of\ product\ j\ stored\ in\ period\ i$
$w_{(i)} = Number\ of\ work\ shifts\ in\ period\ i$
$v_{(j,i)} = \{1\ if\ setup\ is\ made, 0\ otherwise\}$

- ***Objective function:***

$$MinZ = \sum_j^J \sum_i^I \left(B_{(j)} * x_{(j,i)}\right) + \sum_j^J \sum_i^I \left(C_{(j)} * y_{(j,i)}\right) + \sum_i^I \left(CP_{(i)} * w_{(i)}\right) + \sum_j^J \sum_i^I \left(CM_{(j)} * v_{(j,i)}\right) \quad (1)$$

- ***Restrictions:***

Stock balance:

$$S_{(j)} + x_{(j,1)} - D_{(j,1)} = y_{(j,1)}, \forall_j \quad (2)$$

$$y_{(j,i-1)} + x_{(j,i)} - D_{(j,i)} = y_{(j,i)}, \forall_j, \forall_i \geq 2 \quad (3)$$

Maximum storage capacity:

$$\sum_{j=1}^{CARD(j)} V_{(j)} * y_{(j,i)} \leq S_{max}, \forall_j, \forall_i \quad (4)$$

Maximum production capacity:

$$\sum_{j=1}^{CARD(j)} (P_{(j)} * v_{(j,i)} + T_{(j)} * x_{(j,i)}) \leq TPmax_{(i)} * w_{(i)}, \forall_j, \forall_i \quad (5)$$

Non − negative:

$$x_{(j,i)}, y_{(j,i)}, w_{(i)} \geq 0, \forall_j, \forall_i \quad (6)$$

Binary variable, 1 *if setup is made*, 0 *otherwise*:

$$v_{(j,i)}\{1, 0\} \quad (7)$$

Activación de preparación de máquinas:

$$x_{(j,i)} \leq BigM * v_{(j,i)} \quad (8)$$

5 Validation of the Mathematical Model

5.1 Case Study Company

This manufacturing company is located in Colombia and belongs to the agro-chemical industry. It also has presence in other countries in the Americas and is dedicated to manufacturing rice crop protection products. Consequently, it expects substantial growth and market acceptance, thanks to the quality of its products and because rice is a major commodity consumed worldwide. It is strategically located in Colombia to benefit from the country's maritime shipping routes, which facilitates both local and international distribution, as well as the reception of imported raw materials for production. It has a good commercial strategy and a well-known global brand, as well as strategic partnerships with distributors and rice plantation owners, to promote solid growth in the market.

5.2 Problem

Companies in the agro-chemical industry depend heavily on the stability of their sector, because demand and production in Colombia are substantially affected by unforeseeable factors such as the weather. In order to remain in the market, they must incur in substantial costs and maintain large stocks of non-ordered products on hand in order to be able to manage adequate lead times. Consequently, production planning represents a major challenge, in terms of managing resources and establishing work plans, including programming the shifts and personnel involved in the process; the quantities of the different types of products to be produced each month; inventory turnover so as not to overburden the warehouse with unsold and non-ordered products, and scheduling overtime shifts to cover stock outages, as well as other factors that increase uncertainty and are intrinsically associated with the process.

Based on the above, the purpose is to propose an alternative with the support of linear programming models to find an optimal solution to minimize production costs, taking into consideration all the above factors.

5.3 Implementation

The statistics for the subproblem are 77 equations, 100 integer variables, 30 of which are binary variables. The coding for the solution of the problem was done on the AMPL Software using the GLPK solver, in a computer with an AMD Ryzen 3 2.6 Ghz processor and 8 GB of RAM. The computational time to generate each point was 5.5 s: Using the model, savings of $ 550,687,281 were found in total costs.

The last 6 months of the previous year were used as baseline for the study, for the effects of forecasting the linear programming model for the current period. The following input data of the model is shared in the following Appendix Link 1.

Input Data:

1. Demand: Quantity of products requested by customers each month. (See Appendix 1)
2. Initial inventory: Stock of products available for sale at the start of each period. (See Appendix 2)

$$Units\ produced - Demand = Initial\ Stock, month\ 1 \tag{9}$$

$$\begin{aligned} Prev\ Initial\ Stock + Units\ produced - Demand \\ = Initial\ Stock\ P \geq 2, for\ month\{2, 3, 4, 5, 6\} \end{aligned} \tag{10}$$

3. Maximum storage capacity: Maximum space available to store products in cm^3. (See Appendix 3)

$$Height \times Length \times Depth = CA_{max} \tag{11}$$

4. Volume: Volumetric measurement of each product for storage. (See Appendix 3)

$$Height \times Length \times Depth = Product\ type \tag{12}$$

5. Maximum production time: The number of minutes available in each month for production. (See Appendix 4)

$$Days\ month \times T.480\,min = TP_{max} \times Shift \tag{13}$$

$$Days\ month \times 1,440\,min = TP_{max} \times Month \tag{14}$$

6. Time to manufacture the product: Number of minutes required to manufacture each type of product. (See Appendix 5)

$$\frac{Run\ time(\mathrm{min})}{Number\ of\ Units\ Produced} = TF \times P \tag{15}$$

7. Product changeover time: Number of minutes required to clean the machine for the next production run.

$$T.A \leq 30\,min \tag{16}$$

8. Manufacturing cost: The cost to manufacture one unit. (See Appendix 1)

$$CFT = MP + CIF + G.OPER. \tag{17}$$

$$\frac{Total\ manufacturing\ cost}{Number\ of\ Units\ Produced} = CP \times UNIT \tag{18}$$

9. Storage cost: The cost of storing one unit of each product. (See Appendix 1)

$$\frac{Storage\ cost}{Number\ of\ units\ stored} = CA \times UNIT \tag{19}$$

10. Work shift cost: Labor cost of one shift. (See Appendix 1)

$$Cost\ of\ shift \times Shifts\ per\ month = CT \tag{20}$$

11. Setup cost the machine: The cost of preparing the machine for the next run. (See Appendix 1)

$$Setup\ cost \times No.\ of\ changes\ in\ month = CM \tag{21}$$

The total costs and times were calculated for each product, and the times were expressed in terms of minutes.

5.4 Comparison of the Proposed Model to the Current Planning System

Verification was performed using the actual data from the previous semester compared to the results of the mathematical model, with the aim of minimizing the production costs involved in manufacturing the 5 products.

Satisfactory results were found in the comparison, producing an 11% reduction in overall costs, as displayed in Fig. 2, which indicates the change in cost by type during the 6 months of production (See Fig. 2).

Storage cost displayed a cost reduction of 64% in the amount of $29.673.353, against current cost of $46.327.373 and modeled cost of $16.654.020.

Setup cost displayed a cost reduction of 33% in the amount of $5.237.477, against current cost of $15.712.431 and modeled cost of $10.474.954.

Work shift cost displayed a cost reduction of 12% in the amount of $2.554.135, against current cost of $21.863.799 and modeled cost of $19.309.664.

Production cost displayed a cost reduction of 11% in the amount of $513.221.316, against current cost of $4.774.584.746 and modeled cost of $4.261.363.430.

The data modeling produced an improved production programming for the next 6 months, for the effects of viewing a better alternative to help fulfill the objectives in terms of expected demand and cost reduction (See Tables 2 and 3).

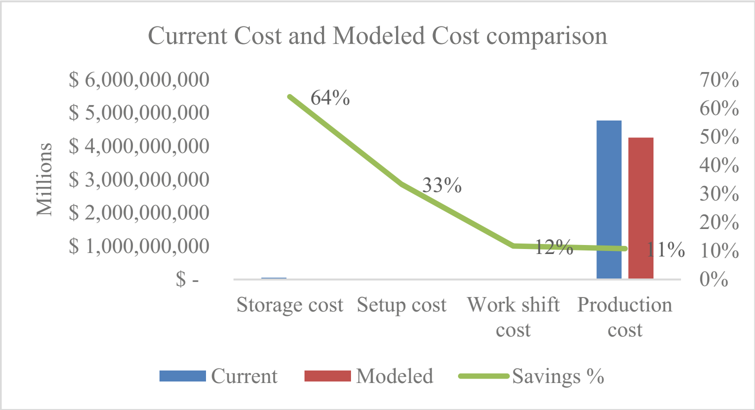

Fig. 2. Comparison of current cost and modeled cost.

Table 2. Forecast of units produced by type of product for 6 months (Current Process).

Product	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Total
Prod. 1L	0	0	0	4.008	0	1.188	5.196
Prod. 4L	1.500	0	0	3.000	0	1.800	6.300
Prod. 20L	750	150	2.400	2.000	3.613	5.902	14.815
Prod. 60L	0	316	140	0	74	200	730
Prod. 200L	294	200	15	100	500	674	1.783

Table 3. Forecast of units produced by type of product for 6 months (Modeled Process).

Product	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Total
Prod. 1L	0	0	0	706	0	4.476	5.182
Prod. 4L	1.488	0	0	2.061	1596	0	5.145
Prod. 20L	0	0	3.325	1.693	1.928	5.798	12.744
Prod. 60L	464	0	0	0	0	0	464
Prod. 200L	269	0	0	169	639	632	1.709

The benefits of the new planning from linear programming are reflected in the costs of storage and setup, with reductions of 64% for storage and 33% in setup (see Fig. 3).

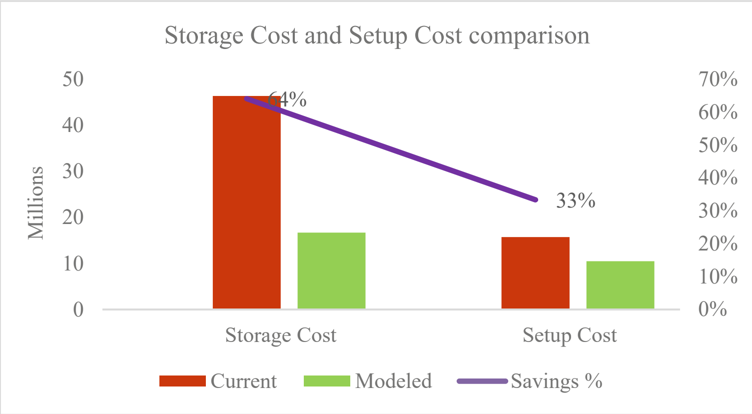

Fig. 3. Comparison of reduction of storage costs and setup costs.

The above demonstrates the effectiveness of the model, which produced suitable information for decision-making.

6 Sensitivity Analysis

A sensitivity analysis was carried out to determine how the variations of some parameters affect total production costs, storage costs, work shift cost, setup cost, and the optimized total cost. This analysis is carried out by making variations by −50, −25, +25, and 50% in the values of the parameters: manufacture time, production cost per product, maximum production time, work shift cost by period, and setup time. The data of the parameter's variation and sensitivity analysis results are shared in the following Appendix Link 2.

The table in Appendix 9 shows the results of the parameters variation in the costs of the proposed model, which allows us to analyze the influence of these parameters on the model results. For the total production costs, there is a significant influence $B_{(j)}$ that represents the production cost for each product, observing changes by increasing and decreasing the values for the five products, with a directly proportional behavior.

In storage costs, a significant influence is observed in three of the five parameters analyzed. A growth in storage costs is observed by increasing the manufacturing time $T_{(j)}$. However, this behavior isn't proportional to the time of decreasing the time. Regarding the maximum manufacturing time TP_{max}, a significant influence is observed in the variation of its values per period, showing a decreasing behavior when increasing the time and increasing when decreasing it. In the case of preparation time $P_{(j)}$, it proportionally influences variations above and below this time, showing a significant influence.

Additionally, it can be observed how work shift costs are sensitive to changes in some of the parameters under study, such as manufacturing time $T_{(j)}$ and work shift cost CP. In the case of the maximum manufacturing time TP_{max}, an inversely proportional behavior is observed, due to with increasing time a decreasing behavior is observed and when decreasing it is increasing.

Furthermore, the cost of preparation is sensitive to changes in some parameters. As the manufacturing time increases $T_{(j)}$, the values increase proportionally, as well as decreasing them. In the case of maximum manufacturing time TP_{max}, the cost increases by increasing it by 25% and 50%, keeping the same value ($ 11,971,400). As the percentage decreases, the cost rises to 25% and then decreases to 50%, with an atypical behavior that does not follow a pattern. There is only a variation in setup costs as the setup time $P_{(j)}$ parameter decreases.

Finally, from the results obtained in the sensitivity analysis on the total cost of the model, it can be concluded that the parameter that has the most significant influence is the production cost of each product $B_{(j)}$, followed by the time of manufacture $T_{(j)}$.

7 Conclusions

Mathematical models are able to solve real company programs and everyday events in an optimal manner, enabling making informed decisions that reduce uncertainty and error. This tool offers numerous benefits, including improved forecasting and use of resources, detecting shortcomings or restrictions, a basis for decision-making, reducing costs, anticipating future events, optimal solutions, among many other benefits.

As with other linear production models, this study shows how improved production planning based on demand enables obtaining obtain economic benefits, thereby improving business profitability and making better use of resources, in terms of deciding what, how much and when to produce. The adequate definition of the system's parameters and variables enabled obtaining a lineal model to minimize costs and optimize resources, which helped achieve a considerable cost reduction in terms of product storage by 64%, setup cost by 33%, the number of work shifts per month by 12%, and production cost by 11%. Overall costs decreased by 11%, which will represent a substantial forecast economic benefit for production in the next 6 months.

Future projects could take into consideration other parameters to provide a broader picture of the production process and help minimize other product costs, such as distribution costs, distribution programming and storage area availability.

References

1. Market Research. https://marketresearch.biz/report/crop-protection-chemicals-market/. Accessed 29 Mar 2021
2. Universidad ESAN. https://www.esan.edu.pe/apuntes-empresariales/2016/07/reduccion-de-costos-con-eficiencia/. Accessed 29 Mar 2021
3. Camino Financial. https://www.caminofinancial.com/es/como-reducir-los-costos-de-produccion-de-tu-empresa/. Accessed 29 Mar 2021
4. Paredes Roldán J.: Planificación y control de la producción, 1ra edn. IDIUC, Instituto de Investigación Universidad de Cuenca (2001)
5. Frontoni, E., Marinelli, F., Rosetti, R., Zingaretti, V.: Optimal stock control and procurement by reusing of obsolescences in manufacturing. Comput. Ind. Eng. **148** (2020). https://doi.org/10.1016/j.cie.2020.106697
6. Peña, I., Santa Cruz, R.: Modelo de Planeación de la Producción para una Empresa Agroindustrial. Acta Nov. **1**(2), 181–189 (2001)

7. Cáceres, D., Reyes, J., García, M.: Modelo de Programación Lineal para Planeación de Requerimiento de Materiales. Rev. Tecnológica ESPOL – RTE **28**, 24–33 (2015)
8. Sabah, B., Nikolay, T., Sylverin, K. T.: Production planning under demand uncertainty using Monte Carlo simulation approach: a case study in fertilizer industry. In: Proceedings of the 2019 International Conference on Industrial Engineering and Systems Management, IESM, pp. 1–5 (2019). https://doi.org/10.1109/IESM45758.2019.8948112
9. Marimin, M., Zavira, R.: Production planning of crude palm oil: a study case at X Co. IOP Conf. Ser.: Earth Environ. Sci. **472**(1) (2020). https://doi.org/10.1088/1755-1315/472/1/012047
10. Valencia, E.T., Lamouri, S., Pellerin, R., Dubois, P., Moeuf, A.: Production planning in the fourth industrial revolution: a literature review. IFAC-PapersOnLine **52**(13), 2158–2163 (2019). https://doi.org/10.1016/j.ifacol.2019.11.525
11. Schuh, G., Prote, J.P., Sauermann, F., Franzkoch, B.: Databased prediction of order-specific transition times. CIRP Ann. **68**(1), 467–470 (2019). https://doi.org/10.1016/j.cirp.2019.03.008
12. Hahn, G.J., Brandenburg, M.: A sustainable aggregate production planning model for the chemical process industry. Comput. Oper. Res. **94**, 154–168 (2018). https://doi.org/10.1016/j.cor.2017.12.011
13. Charoenponyarrat, D., Somboonwiwat, T.: Aggregate planning in canned pineapple production lines. In: 2018 5th International Conference on Industrial Engineering and Applications, ICIEA 2018, pp. 349–354 (2018). https://doi.org/10.1109/IEA.2018.8387123
14. Nahmias, S.: Análisis de la producción y las operaciones, 5ta edn. The McGraw-Hill Companies Inc., Mexico (2007)
15. Schito, J., Moncecchi, D., Raubal, M.: Determining transmission line path alternatives using a valley-finding algorithm. Comput. Environ. Urban Syst. **86** (2021). https://doi.org/10.1016/j.compenvurbsys.2020.101571
16. Baykasoğlu, A., Özbel, B.K.: Modeling and solving a real-world cutting stock problem in the marble industry via mathematical programming and stochastic diffusion search approaches. Comput. Oper. Res. **128** (2021). https://doi.org/10.1016/j.cor.2020.105173
17. Prifti, V., Dervishi, I., Dhoska, K., Markja, I., Pramono, A.: Minimization of transport costs in an industrial company through linear programming. IOP Conf. Ser. Mater. Sci. Eng. **909**(1) (2020). https://doi.org/10.1088/1757-899X/909/1/012040
18. Andres, B., Guzman, E., Poler, R.: A novel MILP model for the production, lot sizing, and scheduling of automotive plastic components on parallel flexible injection machines with setup common operators. Complexity **2021**, 1–16 (2021). https://doi.org/10.1155/2021/6667516
19. Yudhatama, J., Hakim, I.M.: Truck assembly line reconfiguration to reduce cycle time with lean manufacturing approach in the Indonesian automotive industry. IOP Conf. Ser. Mater. Sci. Eng. **1003**(1) (2020). https://doi.org/10.1088/1757-899X/1003/1/012101
20. Bellingeri, A., Gallo, A., Liang, D., Masoero, F., Cabrera, V.E.: Development of a linear programming model for the optimal allocation of nutritional resources in a dairy herd. J. Dairy Sci. **103**(11), 10898–10916 (2020). https://doi.org/10.3168/jds.2020-18157
21. Asmara, S., Rahmawati, W., Suharyatun, S., Wibowo, S.A.: Optimalization of upja revenue (business provider services) rice cultivation using linear programing analysis in seputih raman district, central Lampung. IOP Conf. Ser. Earth Environ. Sci. **355**(1) (2019). https://doi.org/10.1088/1755-1315/355/1/012087